United States General Accounting Office

GAO

Fact Sheet for the Committee on Science, Space, and Technology, House of Representatives

May 1991

FEDERAL RESEARCH

SEMATECH's Efforts to Develop and Transfer Manufacturing Technology

GAO/RCED-91-139FS

Accession Number: 5338

Publication Date: May 10, 1991

Title: Federal Research SEMATECH's Efforts To Develop And Transfer Manufacturing Technology

Corporate Author Or Publisher: U.S. General Accounting Office, GAO, Washington, DC 20548 Report Number: GAO/RCED-9-139FS

Descriptors, Keywords: Sematech GAO Technology Transfer Government Industry Research Semiconductor Manufacture Equipment Material Objective ETAB

Pages: 16

Cataloged Date: May 19, 1995

Copyrighted or Not: N

Document Type: HC

Number of Copies In Library: 000001

Record ID: 30025

Source of Document: GAO

GAO

United States
General Accounting Office
Washington, D.C. 20548

Resources, Community, and
Economic Development Division

B-236639

May 10, 1991

The Honorable George E. Brown, Jr.
Chairman
The Honorable Robert S. Walker
Ranking Minority Member
Committee on Science, Space, and
Technology
House of Representatives

You requested that we annually review SEMATECH, a government-industry research consortium formed in 1987 to further semiconductor manufacturing technology and enable the U.S. semiconductor industry to regain world manufacturing leadership. Our previous reports focused on SEMATECH's start-up activities and its efforts to strengthen equipment and materials suppliers. (See the list of related GAO products at the end of this fact sheet.)

As agreed with your offices, this fact sheet provides some preliminary information about SEMATECH's (1) progress in achieving its technological objectives and (2) efforts to transfer the resulting technology to its 14 member companies. This information is primarily based on interviews with 7 of the 14 members of SEMATECH's Executive Technical Advisory Board. We plan to continue our overall assessment of the consortium's progress and report to you in the fall of 1991 to coincide with the debate over the reauthorization of federal funding for SEMATECH.

In summary, in regard to achieving SEMATECH's technological objectives, the seven executives we interviewed stated that they generally are satisfied with SEMATECH's (1) overall research priorities, (2) progress on 54 ongoing research projects, and (3) management control over its research program. The executives noted, however, that SEMATECH's projects with the two principal U.S. suppliers of lithography equipment—one of the most critical pieces of equipment for fabricating the next generation of semiconductors—are behind schedule. It is unclear whether these companies will generate sufficient equipment sales to become competitive in the world market.

Regarding SEMATECH's technology transfer efforts, all of the member company executives we interviewed pointed to useful technology and know-how that their companies have received from SEMATECH. In particular, they cited the effectiveness of SEMATECH's assignee program, in which researchers and managers from the member companies typically

work at SEMATECH for 2 years. In addition, they told us that SEMATECH has contributed to their companies' improved operations through such efforts as its equipment improvement program and its equipment qualification program for demonstrating the equipment's performance capabilities.

Section 1 of this fact sheet discusses SEMATECH's technological progress, and section 2 discusses SEMATECH's technology transfer activities. To obtain this information, we interviewed seven members of SEMATECH's Executive Technical Advisory Board, reviewed the management report that SEMATECH uses to evaluate the technological progress of each research project, and interviewed SEMATECH officials. The Executive Technical Advisory Board members we interviewed are from Advanced Micro Devices, Inc.; Hewlett-Packard Company; Intel Corporation; International Business Machines (IBM) Corporation; LSI Logic Corporation; National Semiconductor Corporation; and Texas Instruments, Inc. We selected these board members to include member companies with different types of semiconductor manufacturing operations and sales volumes, and we selected them on the basis of their availability. We plan to interview the other seven Executive Technical Advisory Board members as part of our overall assessment of SEMATECH's progress. The glossary at the end of this fact sheet provides definitions of semiconductor manufacturing terminology that we use. Our work was conducted between October 1990 and March 1991.

We discussed the contents of this fact sheet with officials from SEMATECH and the Department of Defense, who agreed with its technical accuracy.

As agreed with your offices, we are sending copies of this report to the Secretary of Defense; the Chief Executive Officer of SEMATECH; and the Director, Office of Management and Budget. We also will make copies available to other interested parties upon request.

Major contributors to this fact sheet are listed in appendix I. If I can be of further assistance, please contact me at (202) 275-5525.

John M. Ols, Jr.

John M. Ols, Jr.
Director, Housing and Community
Development Issues

Contents

Abbreviations

ETAB	Executive Technical Advisory Board
GAO	General Accounting Office
SEMATECH	SEmiconductor MAnufacturing TECHnology

SEMATECH's Technological Progress

Question

What progress is SEMATECH making to meet its overall goal of providing the U.S. semiconductor industry with the domestic capability for world leadership in manufacturing?

Information Obtained

SEMATECH primarily has focused on strengthening critical segments of the U.S. semiconductor equipment industry by working with individual suppliers on projects to improve the performance of their equipment. SEMATECH has given priority to projects in lithography; multilevel metals; manufacturing methods, processes, and systems; and furnaces and ion implantation. As of February 7, 1991, SEMATECH had completed 9 projects and had 54 underway.

The seven member company executives we interviewed on SEMATECH's Executive Technical Advisory Board (ETAB) stated that:

- They are generally satisfied with the projects SEMATECH has undertaken because these projects are needed to regain semiconductor manufacturing leadership.
- To date, SEMATECH is making satisfactory progress on the projects. However, with most SEMATECH projects scheduled for completion in late 1991 and 1992, it is too early to judge the effect that these projects will have on strengthening the U.S. semiconductor industry.

In addition, one ETAB executive said that his company expects that the results of many of SEMATECH's projects will start to be incorporated into his company's operations later in 1991, SEMATECH's fourth year of operations. He added that SEMATECH's first year centered on defining its program, the second year on establishing an organization and focus, and the third year on developing the program.

Because of differences between member companies, the time at which SEMATECH-developed technology becomes useful to their operations varies. Even when more advanced equipment becomes available, a member company may need to wait until an appropriate time, such as when it constructs a new fabrication facility, before incorporating the equipment into its operations.

Question

Does SEMATECH have a comprehensive program management plan to govern its research program?

Information Obtained

In 1990 SEMATECH's management began using a master deliverables list to monitor and evaluate the progress of each of its research projects. The master deliverables list provides detailed information about definition, objectives, approach, and milestones for each project. For example, it typically provides milestones for such key events for a project as defining equipment specifications, delivering equipment to SEMATECH, and completing SEMATECH's characterization and qualification work on equipment.

In response to SEMATECH's request for feedback in late 1990, member companies gave the master deliverables list an overall rating of "adequate" for project definition. This rating indicated that companies generally had sufficient information to assess each project's scope, timing, objectives, and technological information to be delivered. SEMATECH's Technical Communications Office, which completed its report on member company feedback on March 28, 1991, also provided member companies' comments about individual projects to SEMATECH management and the appropriate project managers.

Six of the seven ETAB executives we interviewed were generally satisfied with the tasks being accomplished on the projects. The other executive referred us to his company's response to SEMATECH's request for feedback, which stated that 36 projects were adequately defined while 15 needed better definition. The company did not evaluate 6 of the 57 projects that were active as of October 1990.

Question

Are SEMATECH's technical milestones being achieved on a schedule specified in its management plan?

Information Obtained

As part of their evaluation of the master deliverables list, the 14 member companies were asked to assess the timeliness of each of the 57 active projects as of October 1990. Overall, the member companies responded that (1) 40, or 70 percent, of the 57 projects either were on schedule or averaged at most 2 months behind their required dates and (2) 17, or 30 percent, were from 2 to 5-1/2 months behind schedule. Ten of the 17 projects were among 23 that the ETAB rated as "high priority" in May 1990.

The seven ETAB executives we interviewed stated that they were (1) generally satisfied with SEMATECH's progress on its 54 active projects as of the beginning of 1991 and (2) confident that SEMATECH's projects were

under adequate management control and oversight. Three of the ETAB executives added that SEMATECH's management of these projects was comparable to the management of similar projects within their own companies. One executive noted that SEMATECH's top management has made a strong commitment to its members to deliver on schedule what was promised.

Question

How has SEMATECH's initiatives to improve relations between the 14 member companies and key suppliers enhanced the member companies' manufacturing operations and affected their communications with suppliers?

Information Obtained

Because its member companies represent 80 percent of the U.S. semiconductor manufacturing production, SEMATECH is in a position to address industrywide issues. For example, in June 1990 SEMATECH's member companies approved Partnering for Total Quality guidelines for improving manufacturer-supplier relations. The guidelines call for semiconductor manufacturers to work more closely with their key U.S. suppliers, among other things, by (1) sharing strategic goals and plans; (2) giving them greater access to information about the long-term performance of their equipment; (3) providing them with competitive analysis information; and (4) supporting their product development work. SEMATECH also has promoted the development of industry equipment and measurements standards and met with equipment suppliers to suggest ways to improve their operations and products.

The 7 ETAB executives we interviewed stated that the 14 member companies needed to establish closer working relationships with their key suppliers because improved relations would enhance their companies' manufacturing operations. Five of the seven ETAB executives added that their companies had taken steps to establish better relationships with their key suppliers as a result of SEMATECH's initiatives.

One ETAB executive noted that many U.S. equipment suppliers have had process, mechanical, and design problems. Improved relationships with suppliers have changed past practices of denying that a problem existed to admitting that problems exist and working together to solve them. Another executive pointed out that partially because SEMATECH's members represent 80 percent of the suppliers' U.S. customer base, (1) suppliers have been more receptive to SEMATECH's input into their operations and (2) SEMATECH is able to accelerate the development of industrywide

standards that will make the U.S. semiconductor equipment industry more efficient.

Question

What is the status of SEMATECH's work on lithography steppers—critical equipment for which U.S. suppliers have technologically fallen behind foreign competitors?

Information Obtained

SEMATECH has equipment development contracts with GCA (a subsidiary of General Signal Corporation) and Silicon Valley Group Lithography Systems, formerly the optical lithography division of Perkin-Elmer Corporation. The joint development project for GCA's XLS lithography stepper is behind schedule, and the equipment still is experiencing problems with the lens. The Silicon Valley Group project got a late start because of the delay in contract award caused by the sale of Perkin-Elmer.

The seven ETAB executives, noting the competitive strength of foreign lithography equipment companies, were uncertain whether either company will generate sufficient equipment sales to become competitive in the world market. The executives noted that whether the U.S. companies will have sufficient equipment sales to become competitive depends upon their timing and ability to demonstrate competitive equipment.

Three of the ETAB executives expressed concern that schedule slippage for the XLS stepper project may result in GCA's missing the "window of opportunity" for selling the leading edge generation of equipment. Three other executives told us that GCA had gone from no chance of regaining competitiveness in the world market to some chance as a result of the SEMATECH project. One executive noted that Nikon Corporation needed 10 years to take a significant market share in lithography equipment from GCA, so it would be unrealistic to expect GCA to regain lost market share in such a short period of time.

Because the Silicon Valley Group is developing fundamentally different lithography stepper technology from that of other major lithography equipment suppliers, one ETAB executive suggested that it may provide the United States with a leader in the field even if GCA does not succeed.

SEMATECH's Efforts to Transfer Technology to Its Member Companies

Question

How does SEMATECH's process for sharing technological data operate?

Information Obtained

Technology is shared through a variety of mechanisms, including assignees from member companies, the ETAB and other technical advisory boards, visits by technical delegations from member companies, workshops, and seminars. In addition, SEMATECH provides members with reports and videos on specific technology development projects.

Of the seven ETAB executives we interviewed, five said that "people-to-people interaction" through member company assignees was the most effective mechanism for technology transfer. One ETAB executive cited workshops and seminars, including equipment users groups and competitive analysis studies, as most effective. The remaining ETAB executive told us that reports providing actual documentation were most effective.

Two ETAB executives told us that recent visits to SEMATECH by their companies' senior management had resulted in greater confidence about the potential benefits that SEMATECH's program could have on their companies' operations.

Question

How is the SEMATECH assignee program working? Are member companies providing high-quality assignees? Are the experiences that assignees receive at SEMATECH making them more valuable employees to the member companies?

Information Obtained

Assignees play a major role in transferring technology from SEMATECH to member companies. As of March 27, 1991, 212 assignees were among 335 employees in management and technical positions in SEMATECH's operating divisions. The number of assignees from individual member companies ranged from 2 to 38.

Overall, the seven ETAB executives rated the assignee program as "very effective." Five executives rated the quality of assignees as "high" or "very high" in relation to the tasks to be performed. The other two executives commented only on the quality of the assignees their companies had sent, which they rated as "high." The seven ETAB executives believed that assignees' experience at SEMATECH would make them more valuable employees to their member companies. One ETAB executive said that by working with engineers from other companies, assignees

obtained a broader perspective that would contribute to better member company decision-making. The ETAB executives told us that the mix of assignees and SEMATECH's permanent employees seemed appropriate.

Question

To what extent are member companies that benefit from SEMATECH-developed technologies deploying these technologies in their manufacturing operations?

Information Obtained

All seven ETAB executives stated that SEMATECH's research results have contributed to improvements in their companies' operations.

- Four ETAB executives told us that their companies have incorporated SEMATECH's methodologies for evaluating and improving equipment for their manufacturing operations. These executives particularly cited SEMATECH's equipment qualification program for demonstrating the equipment's performance capabilities as beneficial.
- Two executives said that their companies had used the fabrication facility design and construction technologies that SEMATECH developed for its facility in constructing new fabrication facilities.
- One executive stated that because his company owns and operates nearly all of the equipment in SEMATECH's equipment improvement program, it has incorporated virtually all of the improved equipment into its operations.
- Two executives mentioned that their companies had incorporated defect control and yield management tools and methodologies into their operations.
- The ETAB executives also cited the following examples of SEMATECH-developed technologies that their companies have incorporated: a factory-modeling system, manufacturing production metrics, a deionized water ozone injection system used to continuously control the levels of bacteria in a fabrication facility's water, and GCA's ALS autostep lithography stepper.

Question

Have member companies' planned purchases of foreign equipment for their fabrication facilities decreased as a result of their participation in SEMATECH?

Information Obtained

According to the ETAB executives, their companies will probably begin to buy more semiconductor manufacturing equipment from U.S. suppliers

in the near future as a result of SEMATECH's equipment development program.

- Two executives stated that their companies are currently considering purchasing several key pieces of equipment from U.S. suppliers that they would not have considered before SEMATECH.
- One executive told us that his company has delayed its decision whether to purchase a key piece of equipment for three of its fabrications facilities in order to evaluate a U.S. supplier's equipment that had been improved at SEMATECH.
- Three executives said that although their companies had not yet changed any of their purchasing plans, they probably would shift purchases to U.S. equipment suppliers in the future as a result of SEMATECH's program. One of these executives added that his company had reduced the number of foreign companies on its list of preferred suppliers for two key equipment areas because of SEMATECH's progress in improving U.S. suppliers' equipment.
- One executive, noting that his company already purchased 90 percent of its semiconductor equipment from U.S. firms, said that no change has occurred in its purchasing plans as a result of SEMATECH's equipment development program.

In addition, SEMATECH managers told us that a member company that we did not contact has substantially increased the percentage of U.S.-made semiconductor equipment that it plans to install in a new fabrication facility as a result of improvements made through SEMATECH's equipment development projects.

Question

Has SEMATECH benefited from semiconductor manufacturing research conducted at federal laboratories?

Information Obtained

SEMATECH has ongoing research efforts with the Department of Commerce's National Institute of Standards and Technology and the Department of Energy's Sandia National Laboratories and Oak Ridge National Laboratory. Five of the seven ETAB executives believe that Sandia's equipment reliability program assisting equipment suppliers is particularly useful. One executive noted that Oak Ridge's project to develop next-generation etching equipment is high risk, but if successful, it would be very important to the industry.

While the ETAB executives expressed satisfaction with these jointly funded projects, they cited limitations in working with federal laboratories on other semiconductor manufacturing research. Five of the executives told us that they would like the federal laboratories' research to focus more on areas that would benefit the U.S. semiconductor industry. Four executives said that federal laboratories and the semiconductor industry need to communicate and coordinate more for the laboratories' research to be useful to industry. One executive, while noting that the laboratories have a great deal of expertise and a willingness to assist industry, stated that collaborating on research is hampered by the amount of funds the federal laboratories need to begin work.

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Glossary

Deposition	An operation that places a film on a wafer without a chemical reaction with the underlying layer.
Etching	A process in which acid is used to remove previously defined portions of the silicon oxide layer covering the wafer to expose the silicon underneath. Removing the oxide layer permits the introduction of desired impurities into the exposed silicon through diffusion or ion implantation or the deposition of aluminum paths for electrical interconnection or circuit elements.
Furnace	An oven used, for example, to facilitate the reaction of gases with silicon wafers at temperatures typically greater than 800 degrees Centigrade to form carbon dioxide or to diffuse previously deposited chemicals into the wafer.
Ion Implantation	A process in which the silicon is bombarded with high-voltage ions in order to implant them in specific locations and provide the appropriate electronic characteristics.
Lithography	A process in which the desired circuit pattern is projected onto a photoresist coating covering a silicon wafer. When the resist is developed, portions of the resist can be selectively removed with a solvent, exposing parts of the wafer for etching and diffusion.
Multilevel Metals	This SEMATECH thrust area involves projects in etching, interlevel dielectric and tungsten deposition, and planarization.
Semiconductor	A material, typically silicon or germanium, that has four electrons in its outer ring and is a poor conductor of electricity. The term has come to refer to all devices made of semiconducting material, including integrated circuits, transistors, and diodes.
Stepper	A sophisticated piece of equipment used to transfer an integrated circuit pattern from a glass plate, known as a "mask," onto a disk of semiconductor material, known as a "wafer."

Related GAO Products

Federal Research: The SEMATECH Consortium's Start-up Activities (GAO/RCED-90-37, Nov. 3, 1989).

Federal Research: Assessment of the Financial Audit for SEMATECH's Activities in 1988 (GAO/RCED-90-35, Feb. 16, 1990).

Federal Research: SEMATECH's Efforts to Strengthen the U.S. Semiconductor Industry (GAO/RCED-90-236, Sept. 13, 1990).

Federal Research: Assessment of the Financial Audit for SEMATECH's Activities in 1989 (GAO/RCED-91-74, Apr. 30, 1991).